Aprendizaje entre iguales en Ciencias Naturales de Educación Primaria

Thurston, Allen; Van de Keere, K.; Topping, K. J.; Kosack, W.; Gatt, S.; Marchal, J.

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Peer learning in primary school science: Theoretical perspectives and implications for classroom practice

Allen Thurston[1], K. Van de Keere[2], K.J. Topping[1], W. Kosack[3], S. Gatt[4], J. Marchal[5], N. Mestdagh[2], D. Schmeinck[3], W. Sidor[6], K. Donnert[7]

[1] University of Dundee, Scotland, U.K.
[2] Catholic Polytechnic of South-West-Vlaanderen, Belgium
[3] University of Education, Karlsruhe, Germany
[4] University of Malta, Malta
[5] Academic Inspection of Meurthe and Moselle, France
[6] Teacher Training Center in Lomza, Poland
[7] Liverpool Hope University, England, U.K.

U.K., Belgium, Germany, Malta, France, Poland

a.thurston@dundee.ac.uk

[Include abstract in English and in Spanish, if possible]

Resumen

This article examines cognitive models of peer learning in school and the implications that these models have for the teaching of science in primary schools. The article is a product of the European Commission, Socrates Comenius 2.1 funded project 'The Implementation of Scientific Thinking in (Pre) Primary Schools Settings (STIPPS)' project (www.stipps.info). It reviews literature and examines the models developed to exemplify Piagetian and Vygotskian cognitive models of peer learning. The role that metacognition and affective development play in the peer learning process is explored. Research regarding the implementation of peer learning in school contexts is reviewed and recommendations are made as to a critical typology for the organisation and structure of peer learning in primary school science are made. The article provides a link between cognitive models of peer learning in primary school science and the classroom implementation of such models. The implications for continuing professional development of teachers in respect of the use of peer learning in science are explored and recommendations in this respect are made.

Palabras Clave: peer learning, science, cognitive psychology

Abstract

This article examines cognitive models of peer learning in school and the implications that these models have for the teaching of science in primary schools. The article is a product of the European Commission, Socrates Comenius 2.1 funded project 'The Implementation of Scientific Thinking in (Pre) Primary Schools Settings (STIPPS)' project (www.stipps.info). It reviews literature and examines the models developed to exemplify Piagetian and Vygotskian cognitive models of peer learning. The role that metacognition and affective development play in the peer learning process is explored. Research regarding the implementation of peer learning in school contexts is reviewed and recommendations are made as to a critical typology for the organisation and structure of peer learning in primary school science are made. The article provides a link between cognitive models of peer learning in primary school science and the classroom implementation of such models. The implications for continuing professional development of teachers in respect of the use of peer learning in science are explored and recommendations in this respect are made.

Keywords: peer learning, science, cognitive psychology

TITLE: Peer tutoring in primary school science: Theoretical perspectives and implications for classroom practice

This article was written with the support of European Commission, Socrates Comenius 2.1 funding. The aims of the article are to:

- Examine cognitive models of peer learning that could be applicable to science education
- Review recent research on peer learning in primary schools
- Develop a critical typology for peer learning in primary school science
- Make recommendations regarding the development of science teaching in primary schools settings

Peer tutoring in science can take place in through two main processes. It can take place between peers with an older, or more able peer will tutor a younger peer (or a peer at an earlier stage of cognitive development). This leads to cognitive conflict and is the basis of Piagetian theories of cognitive constructivism. Peer tutoring can also take place with an emphasis on co-construction. In this context the peers will still be at different stages of development, but their relative levels will be closer together. This allows them to co-construct new meaning and cognitive structures from learning experiences. They combine and splice ideas together. This is the basis of Vygotskian co-construction.

Cognitive models of peer learning

Piaget (1978) proposed that understanding developed in children through the processes of assimilation and accommodation, associated with the construction of internal schemas for understanding the world. This has been termed cognitive constructivism. Vygotsky (1978) placed greater emphasis on the role of social interaction, language and discourse in the development of understanding, to allow children to scaffold each other's learning and co-construct. This has been termed social constructivism. Despite the apparent differences between Vygotskian and Piagetian peer learning theories it both require peer interaction (Blatchford, Kutnick, Baines & Galton, 2003). Although peer-peer, rather than pupil-teacher are the dominant forms of interaction in the classroom (Galton, Simon & Croll, 1980; Tizzard, Blatchford, Burke, Farquhar, & Plewis, 1998) teachers often fail to plan effectively for peer-peer interactions (Kutnick, Blatchford & Baines, 2002). Peer relationships can be a motivating context for pupils. In contrast to adult-peer relationships, power is distributed more horizontally and more likely to be shared (Blatchford et al, 2003). Piaget (1932) noted that '*the very nature of the relationship between child and adult places the child apart, so that his thought is isolated*' (p32).

Most students have concepts about science. These concepts can be a rich medium in which to engage in cognitive conflict or co-construction. In Vygotsyan peer learning learners will undertake joint investigations. This technique has been used successfully in primary school reading (Duran & Monereo, 2005), mathematics (Fantuzzo, Davis & Ginsburg, 1995) and it is reported that in peer learning initiative with 11-12 year old pupils that the level of constructive activity was the strongest predictor of raised attainment (Webb, Troper & Fall,1995). Fantuzzo and Ginsburg-Block (1998) reported that peer tutoring based on theories of sociocognitive development and research contributed to academic achievement. Interactions in Vygotskian peer learning contexts will be cooperative with shared questioning, splicing together of the ideas and less hinting and guiding taking place. The peers work together to generate joint

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understanding (Hogan & Tudge, 1999). When these patterns predominate then peer tutoring offers greatest gains to tutees. In Piagetian peer tutoring techniques there is more tutor direction and support. This is more aligned with the cognitive conflict outlined by Piaget. In Piagetian peer learning the adaptation of cognitive structures takes place when assimilation and accommodation are in balance. This balance should be more easily established between peers than between child/teacher resulting in cognitive structures more open to adaptation and less prone to conservation (De Lisi & Golbeck,1999).

The benefits of peer interaction have been reported in science (Howe, Rogers &Tolmie, 1990; Howe, Tolmie, Greer & Mackenzie,1995; Howe, Tolmie, Thurston, Christie, Donaldson, Livingston *et. al.*, 2007). These studies reported that cognitive gains did not necessarily take place during the learning activity, but up to 11 weeks afterwards. However, learning was a direct result of the interaction that took place during the lesson. The discourse acted as a catalyst for subsequent cognitive development. The important elements of discourse reported to facilitate these gains related to talk that took reasoning expressed during the activity by a peer and transformed it in some way. This transformation could include 'splicing' together of ideas, disagreement with a justification, clarification being sought or an idea being elaborated upon (Foot & Howe, 1998; Rohrbeck, Ginsburgh-Block, Fantuzzo & Miller, 2003; Robinson, Schofield & Steers-Wentzell, 2005). A meta-analytic review of peer learning concluded that in nearly every instance of reported intervention in the primary school the technique was demonstrated to be effective at raising attainment (Rohrbeck et al, 2003).

Piagetian cognitive conflict peer learning

Piaget's theories of collaborative learning stem from the theories of equilibration. In this learning model there has to be reconciliation between prior and newly experienced beliefs. The new belief needs to be close enough to the existing belief that the learner can relate it to previous learning. Peer learning is productive so long as beliefs differ and tasks are structured to draw out the conflict between the existing/new belief (Foot & Howe, 1998). This leads to the existing cognitive structure being displaced and a new structure taking its place. The role of peer interaction in this instance would be to instruct, tutor and lead learners towards internal cognitive development. De Lisi and Golbeck (1999) presented a model of how Piagetian principles of peer learning promoted cognitive growth. Cognitive growth was facilitated within the operational cognitive system (i.e. that which controls thinking processes as opposed to the sensory-motor system which controls motor response to stimulus). Hypotheses developed within the operational system are tested with a peer learner. The event may lead to assimilation (the child allowing the event to enter the cognitive structure in order to infer meaning). In turn this leads to accommodation where the cognitive structure is influenced by the event. However, the accommodation does not imply long term change at this point. Retaining the 'correct' cognitive structure over time is a more complex process and relies on the child gaining deeper understanding of the new cognitive structure leading to equilibration (successful modification of the cognitive structure). This results in one of three outcomes. Either the new cognitive model does not manifest itself as different from the existing model (the existing model is therefore reinforced). If 'perturbation' exists between new and old cognitive structures then the child will go through a process of perturbation-regulation-compensation sequences. This may result in the child rejecting the new model and returning to the old model. However, it may also result in the perturbation impelling change in the child's cognitive/conceptual systems and the development of a new cognitive structure. This process is summarised in Figure 1.

Piagetian peer learning techniques have been successfully implemented in schools in literacy, mathematics and science (Webb, 1989; Howe et al, 1995; Robinson et al, 2005). Central to understanding why Piagetian peer tutoring should result in cognitive restructuring are the ideas of cognitive challenge and post-interactive reflections. Peer tutors offer more possibility of congruence between cognitive structures (therefore more likelihood of understanding the difficulties the learner may experience). This is reported to allow peers to engage in effective dialogue (Allen, 1976; Bruner, 1985). Therefore, peer learning contexts can provide the right balance between the disequilibrium caused through cognitive challenge and social exchanges between peers, for effective learning to take place (Palinscar, 1998).

INSERT FIGURE 1 HERE

Vygotskian cognitive co-construction peer learning

Vygotsky (1978) saw mediation as central to the development of higher psychological functioning. He emphasised the essential nature of social dimensions to learning. '*Every function in the child's (cultural) development appears twice: first on the social level and later on the individual level – first between people (interpsychological) and then inside the child (intrapsychological).*'(p56). The importance of peer learning was emphasised in the development of the notion of the Zone of Proximal Development (ZPD) defined as '*the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers'* (p57). Central to functioning within the ZPD are the principals of intersubjectivity leading to more effective intra-psychological functioning. Intersubjectivity can be thought of the extent to which two subjects can engage in conversation and dialogue that transcends their own worlds/minds. Adults can find it difficult to make that transcendence to the world of the child (Donaldson, 1987). Therefore, peers may form a better context for intersubjectivity to facilitate cognition. Vygotsky's psychological model emphasised the role of dialogue in mediated cognitive growth and suggested that learners were able to '*perform...in collaboration with one another that which they have not mastered independently*' (p87). Vygotsky concluded that peer interaction in the learning process was essential to allow internalisation and long term cognitive growth. The peer questions, discusses, debates and extends the thinking of their partner. Topping and Ehly (1998) provide a theoretical model as to how peer learning promotes cognitive gains when Vygotsyan co-construction occurs (Figure 2). This model is outlined below. The model addresses organizational/structural features of the learning interaction, such as:

- maximising time on task and time engaged with task,
- the need for helper and helped to elaborate goals/plans,
- the individualization of learning and immediacy of feedback possible within the one-on-one situation,
- the excitement and variety of a different kind of learning interaction.

In the model peer learning involves tutoring, support and scaffolding from a peer. In order for this to occur then the tutor needs to manage the learning and activities of the tutor to keep them in the ZPD. The peer tutor acts to provide support and scaffolding. This results in co-

construction of new cognitive structures. The advantage of peer learning in this process is that the peer acts as co-learner and therefore, the potential damaging excess of challenge are minimised. In order for peer tutoring to be successful then peer tutors need to manage and modulate the information processing demands upon the learner so they are neither too much, nor too little. The tutor provides a cognitive model of competent performance. This process is challenging for the tutor and in the process of having to monitor learner performance, detect, diagnose, correct and manage misconceptions/errors there is benefit to the tutor. Good communication skills are required by both tutors and tutees. A trusting relationship with a peer who holds no position of authority might facilitate self-disclosure of ignorance and misconception. This should facilitate diagnosis and correction. Modelling of enthusiasm and competence by the tutor could influence the self-confidence of the tutee. A sense of loyalty and accountability to each other might help to keep the pair motivated and on-task.

Topping ands Ehly report that these sub-processes feed into a larger onward process of extending each other's declarative knowledge, procedural skill, and conditional and selective application of knowledge and skills, by, adding to and extending current capabilities (accretion), modifying current capabilities (re-tuning), and rebuilding new understanding (restructuring in areas of completely new learning or cases of gross misconception or error). They state that these processes are somewhat similar to Piagetian concepts of assimilation and accommodation. This should lead to the joint construction of a shared understanding between tutor and tutee–which is inter-subjective. The understanding might not represent 'absolute truth', is firmly situated within the current context of application (Lave & Wenger, 1991; Derry & Lesgold, 1996), but forms a foundation for further progress. Peer learning might also enable and facilitate a greater volume of engaged and successful practice, leading to consolidation, fluency and automaticity of core skills. Much of this might occur implicitly, i.e. without the tutor or tutee being fully aware of what is happening. As this occurs, both tutor and tutee give feedback to each other, implicitly and/or explicitly. Implicit feedback is likely to occur spontaneously in the earlier stages. The quantity and immediacy of feedback to the learner is likely to increase. Explicit reinforcement might stem from within the partnership or beyond it, by way of verbal and/or non-verbal praise, social acknowledgement and status, official accreditation, or even more tangible reward e.g. teacher assessment.

As the learning relationship develops, both tutor and tutee should begin to become more consciously aware of what is happening in their learning interaction, and consequently more able to monitor and regulate the effectiveness of their own learning strategies. This process should lead to gains in meta-cognitive ability. Meta-cognitive is likely to promote more effective onward learning. The learner should start to know what they know, why they know it and how they know it (Woolfolk, 2001; p260). The tutor's involvement in the peer learning process should help the tutor (through enhanced metacognition) exchange information between the long-term memory and the working memory (Eggen & Kauchak, 1997; p260). Peer learning should also allow both tutor and tutee to make affective gains, becoming more confident that they can achieve, and that success is the result of their own efforts. The conclusion drawn by Topping and Ehly is that the process of cognitive development is not actually a linear model. Instead the affective and cognitive outcomes feed back into the originating sub-processes–forming a continuous iterative process and a virtuous circle. As the peer relationship develops, the process should continue to apply as the learning moves from the surface level to the strategic and on to the deep level, and from the declarative into the procedural and conditional.

INSERT FIGURE 2 HERE

The essential similarities and differences between the two techniques that will be researched in the intervention are summarized in table 1.

INSERT TABLE 1 HERE

Peer learning in the school context

Whilst teachers often reported that they utilised peer learning as a teaching and learning strategy in the classroom, previous work reported that this 'peer learning' often actually involved working alone or listening to teacher instruction (Tizzard, Blatchford, Burke, Farquhar & Plewis, 1988; Galton & Williamson, 1992; Galton, Hargreaves, Comber & Pell, 1999). Wilson, Andrew and Sourikova (2001) reported that classroom observations of mathematics lessons indicated that although children were identified as a 'working group', in practice, each child generally undertook work independently. In such learning contexts, children did not get the benefits of the social aspects of learning in a group and talk in these settings, often did not enhance learning (Galton & Williamson, 1992; Galton, Gray & Ruddock, 1999).

An essential element of peer learning contexts is the quality of talk that takes place. Co-operation through talk enables learners to reconstruct and elaborate their ideas through peer dialogue (Bereiter, 2002) and is the primary tool for the joint construction of knowledge by teachers and learners in learning contexts (Mercer, 1996). Talk stimulates students to ascertain and resolve, for themselves, what was confusing or problematic (Brophy, 2002). Groups composed of students who gave more explanations were found to be most effective at promoting attainment in cooperative learning contexts (Slavin, 1996). Group learning contexts characterized by giving or receiving answers without explanation generally showed reduced attainment (Webb, 1989). Talk enables ideas to be jointly explored by learners to develop joint conceptions (Barnes & Todd, 1977). Therefore, it is essential that teachers develop classrooms that establish and maintain effective pupil discourse and dialogue. Vygotsky (1978) placed emphasis on the role of social interaction, language and discourse in the development of understanding. Vygotsky's views on peer assisted learning suggested that in peer interactive contexts children could scaffold each other's learning and engage in co-construction (Baines, Blatchford & Kutnick, 2003). This theoretical basis manifests itself in primary school classrooms as collaborative peer learning.

A number of factors influence the effectiveness of peer learning. These included the age and ability of children undertaking peer learning (Dean, 1992), the management of the classroom environment (Doyle, 1986) and the type of curricular task being undertaken. Science in particular, is reported to lead itself to classroom activities that can create effective contexts for undertaking peer learning (Howe, Tolmie, Duchak-Tanner & Rattray, 2000). The effectiveness of peer learning is influenced by the size and number of groups in a classroom setting. Groups that are too large often result in splintering and the beneficial effects of the group activity may be lost (Galton & Williamson, 1992). Groupings that combined high and middle, and middle and low attaining pupils in groups were reported to be most effective (Webb, 1989).

The attainment of pupils has been demonstrated to be raised through the use of peer learning contexts (Slavin, 1987; Lou, Abrami, Spence, Poulsen, Chambers & D'Apolonia, 1996). Increased attainment in mathematics as a result of adopting effective peer learning strategies have also been reported (Topping, 2002). In a survey of 804 schools, 34 % of schools repor-

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ted that they utilised peer learning as a strategy to promote increased attainment. (Hallam, Ireson & Davis, 2004). Providing structure to peer learning activities was reported to have resulted in more effective group learning contexts and increased attainment in a sample of 223, 13-14 year old pupils in a study in an Australian school setting (Gillies, 2004). This study also concluded that teaching of peer learning skills to students allowed them to perform better in unstructured group settings. As a result, peer learning training for pupils promoted attainment across curriculum areas. Peer learning is therefore a technique used widely to promote attainment in pupils.

Therefore the classroom working arrangements put in place by the teacher heavily influenced the effectiveness of peer learning and the benefits that pupils may derive from the peer learning. In settings where the teacher did not plan effectively and ensure that tasks required group collaboration, then the result was individualised working with little group activity (Kutnick & Rogers, 1994). The need for peer learning in schools has been identified by a number of pervious studies. However, Ninnes (2002) reported that there was little opportunity for group discussion in structured science schemes of work produced by commercial publishers. It was concluded that there was a need for effective peer learning that promoted talk and prompted children to think about science curriculum related issues. Hallam *et al.*, (2004) reported that only 2% of schools had implemented changes in their peer learning strategies due to introduction of the National Numeracy Strategy in England. Given that aspects of problem solving, mental strategies and data handling lend themselves readily to the application of peer learning this was an interesting result. If peer learning is not a feature of commercially produced science schemes then this emphasises the need for teachers to engage with effective CPD to expand their pedagogic knowledge in this important aspect of learning and teaching.

Critical typology for peer learning in primary school science

The theoretical models and associated classroom based research have a number of implications for the organization of peer learning in primary school science. Peer learning is reported to have a number of organizational dimensions (Topping & Thurston, 2007). When planning to undertake peer learning in science some or all of the following organizational dimensions and questions should be considered:

1. What are the objectives of the peer learning initiative? Projects may have cognitive, social and emotional gains. These may include formal academic achievement, affective and attitudinal gains, social and emotional gains, self image and self concept gains, or any combination.
2. What curriculum content is being covered? Science lends itself readily to incorporating peer learning initiatives as it often involves practical investigatory work (Howe, Tolmie, Duchak-Tanner & Rattray, 2000).
3. What are the characteristics of the helpers and the helped? The traditional assumption was that helpers should be the "best learners" (i.e. those most like the professional teachers). However, Piaget's if work may lead us to conclude that the differential between the cognitive model of the learner and the teacher may be too large a gap to cross, then this barrier could also exist between peers. However, if the gap between peers is correct then peers may present information in a more meaningful manner, and at a more precise level for the learner. Another issue is to whether those being helped include all those in the class or targeted on members of a subgroup, e.g. the especially able or gifted, those with disabilities, those considered at risk of under-achievement or failure, or those from ethnic and other minorities. Teachers must also consider whether the initiative take place with same

age or cross age peers? Helpers and helped may be from the same or different years or grades of study. Same age study may be more convenient to organise for the school, but literature suggests that cross age helping may be ore effective at promoting cognitive gains (Topping, Peter, Stephen & Whale, 2004). The added complication is that cross age implies cross ability, but in reality this may not be the case. Some level of cross ability is desirable within the group. Without this there is a danger of 'pooling of ignorance' or even 'meta-ignorance' where the helper might not know that they do not know the correct facts.

4. What contact pattern and constellations are to be established? Some projects operate as peer tutoring with one helper working with a group of peers, but the size of group can vary from two to thirty or more. One to one working is effective for peer tutoring (Topping, 1987) and group sizes of no greater that six have been shown to be effective for cooperative learning in science (Howe, Tolmie, Thurston, Topping, Christie, Livingston, Jessiman, & Donaldson, 2007).
5. What spatial and temporal issues need to be planned for? Peer learning might be scheduled in regular class contact time, outside of this, or in a combination of both, depending on the extent to which it is substitutional or supplementary for regular teaching. Again the demands of cross age peer learning can be an issue in this respect. The venue may change dependent on the context of the learning being undertaken. It may take place in the classroom or in a specialist room for science.

Conclusions

In conclusion it may be reasonable to conclude that peer learning has an important role to play in primary school science. However, in some educational contexts there is a current trend away from using this important classroom strategy. MacNab (2003) reported that in a sample drawn from 170 Local Education Authority and school representatives, 46% of Scottish schools reported less peer learning since the introduction of curriculum initiatives. The drop in reported peer learning may be indicative of teachers losing the ability to apply an effective pedagogical tool in the classroom. This was emphasised by Hutchison (2003) who reported there was a need to ensure that peer learning was effective in classroom contexts, and concluded that education was not just an activity that takes place in a group, but was a group activity. To have maximum impact it is clear that peer learning needs to be embedded into the pedagogy and planning in individual curriculum areas. Therefore, there may be a case for effective continuing professional development programmes to enhance the pedagogy of teachers in using peer learning strategies. Whilst examples of such programme do currently exist (e.g. Topping, 2004; Topping & Thurston, 2004) the team working as part of the STIPPS project aim to develop materials that should be available across the whole of Europe and should be capable of being used in a wide variety of educational contexts.

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Figure 1: Social constructivism through Piagetian conflict (adapted from De Lisi & Goldbeck,1999)

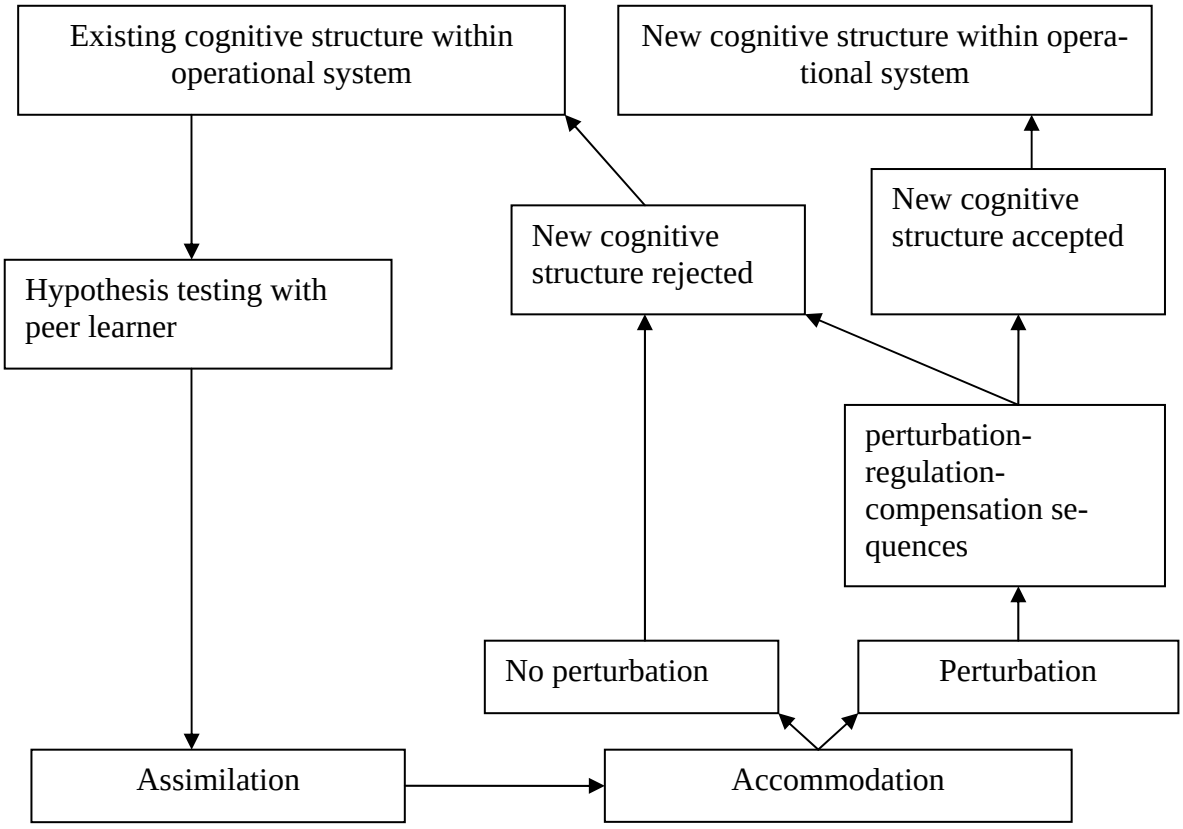
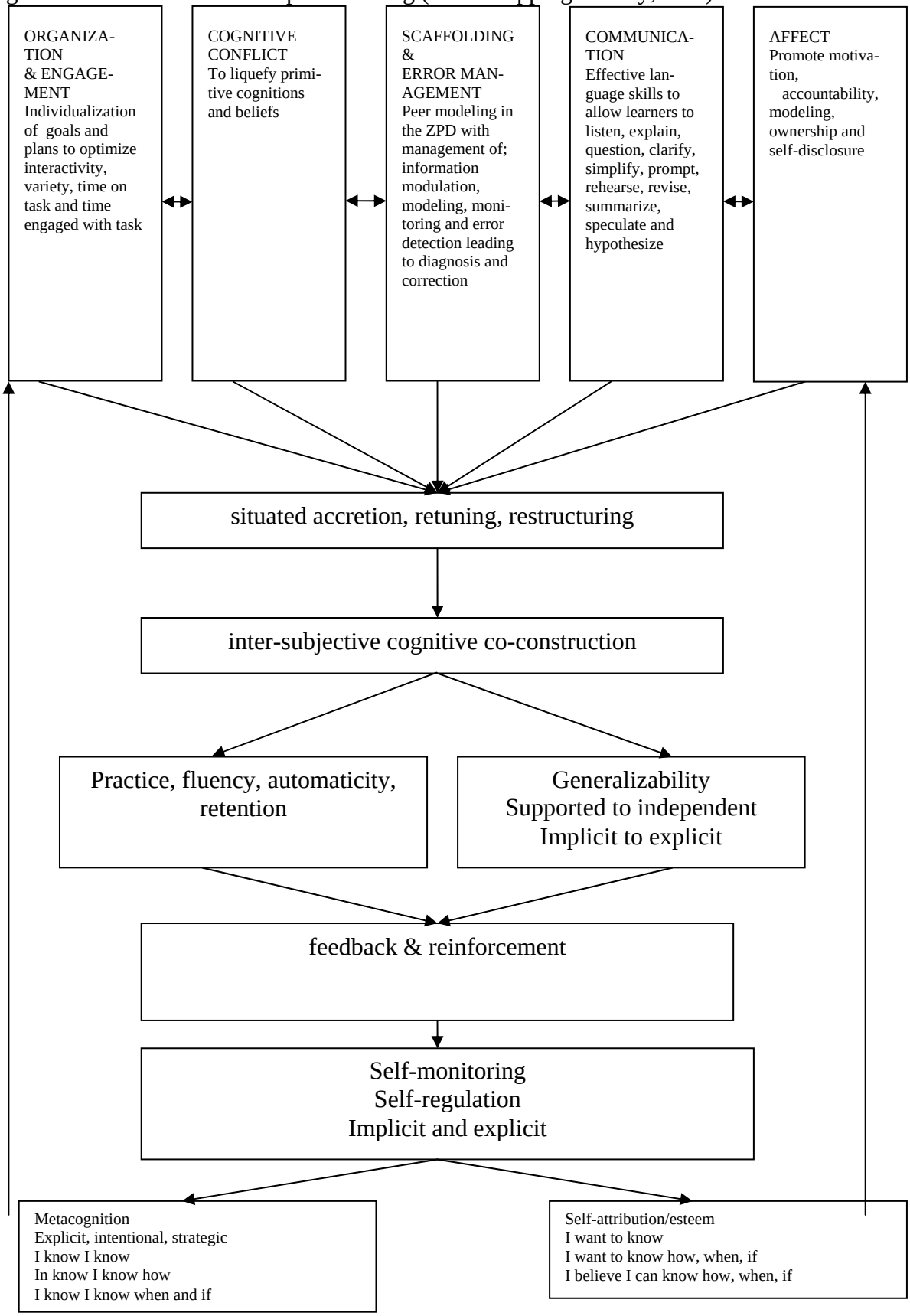


Figure 2:Theoretical model of peer learning (from: Topping & Ehly,1998)



Learning in iterative cycles: Surface → Strategic → Deep
Declarative → Procedural → Conditional

Table 1: Similarities and differences between Piagetian and Vygotskian peer tutoring

Aspect	Piagetian	Vygotskian
Organisation	Takes place with same age, cross ability children. Tutors get access to the 'problem' they will work on with their tutee prior to the lesson and are allowed preparation time.	Takes place with same age, cross ability children. Tutors get access to the 'problem' they will work on with their tutee at the same time as the tutee and therefore, there is no prior preparation time.
Cognitive development	Takes place for the tutor during pre-interactive preparation. Takes place for the tutee as a result of post-interactive reflections.	Takes place for the tutor during the tutoring process. Takes place for both the tutor and the tutee as a result of co-construction during the interactive process.
Expected elements of discourse expected	Questioning and disagreement.	Giving of explanations and slicing together of ideas.
Meta-cognitive developments	Takes place for the tutor during pre-interactive preparation. Takes place for the tutee as a result of post-interactive reflections.	Takes place for the tutor during the tutoring process. Takes place for both the tutor and the tutee as a result of co-construction during the interactive process.
Affective development	Takes place prior to interaction as a result of being assigned to a tutoring role. Takes place for the tutor during pre-interactive preparation. Takes place for the tutee as a result of post-interactive reflections.	Takes place prior to interaction as a result of being assigned to a tutoring role. Takes place for both the tutor and the tutee as a result of tutoring process.
Characteristic elements of talk by pupils during peer tutoring	Exemplifying Questioning Evaluating Disagreeing	Exemplifying Splicing/co-constructing Hinting Leading